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THE CHEMIST: HIS EDUCATION AND HIS JOB*

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In choosing this subject I do not pose as an expert on education. My contacts are confined to the material the Universities have sent us. While I am aware that both chemists and their employers have registered complaints, I am in position to view the question from one angle only, and must leave the solution of the problem to the experienced educator.

The young chemist's field of vision is necessarily narrow. As a student he cannot properly gauge the influence of the things he is taught, and as a graduate he is more or less intolerant because his knowledge is limited. He needs life's experience to teach him, and in the meantime he should give his instructors the benefit of the doubt.

Many young chemists are mislead into the profession. Their choice is often the result of the fascinating influence of the chemical laboratory and the mystery of the science, and they have neither the right temperament nor ability to adapt themselves to this field. The chemical laboratory is very much like the machine shop—the chemist-to-be must expect to see as much hard work, dirt, and grease as he does fine-looking apparatus.

I believe that in undergraduate courses not enough attention is paid to the practical application of principles. Students learn certain laws and fundamentals which lie dormant in their minds until they have to apply them. Then they cannot use them efficiently because they are not arranged so as to be available on an instant's notice.

Often the college graduate finds difficulty in applying common sense. I do not believe that common sense could be taught if absent, but the

* An address delivered before the Syracuse Section of the American Chemical Society.

fact that it must guide us in the application of scientific laws to industrial problems certainly could and should be emphasized.

Mechanical workshop experience is highly desirable in an undergraduate course. In the laboratory constructive work is mostly carried out in glass ware, and outside this field the chemist is frequently lost. I would urge every chemist who wishes to make industry his life work to get acquainted with all materials which are used in chemical construction. If one intends to use cast iron in a project he should know how it is going to behave when he puts something into it. He should be familiar with stresses due to weight as well as the effects of heat and cold on the apparatus. Not only must he know the corrosive effects of chemicals on every structural material, but he must know before undertaking to build an apparatus just how to go about it—what to build out of metal, cement, or wood; what to use for joints, etc., etc.

A frequent complaint is that the young chemist does not use his imagination, a faculty which must be constantly employed in industrial work. When a construction problem is put up to an engineer, all conditions are known. He knows beforehand how much load he is putting on his structures or machine parts. On the other hand, when a chemist is called upon to give an opinion, he must imagine many of his conditions because they are unknown. If he has trained his imagination, he will find it of vital help in weeding out all but the more important factors. A beginner in microscopic work sees so many things that he can hardly distinguish one slide from another, while a trained microscopist can quickly determine the things which are characteristic of each particular slide. Just so the vision of the industrial chemist is obscured by details and he must know what is important and how to pick out that which is essential. He must train his mind in such a way that he is constantly on the lookout for the apparently small but really important things. This he cannot do without imagination.

As an improvement on the educational training of chemists I have a suggestion which I should like to hear debated. I propose to give the student examples to work out on process development and plant construction in connection with his industrial chemistry course. Every chemical reaction equation is suitable for his purpose. The object is to make the student realize, that an equation should be regarded as the possible basis of an industrial process, and to give him a chance to make use of those faculties that are dormant. As it is now, everything is delivered to him. We teach the different processes, as for example, the contact process for making sulphuric acid, by explaining the laws involved, the apparatus necessary, etc. That means the man does not have to dig for data. They are all in the book. All he has to do is memorize them. But suppose we take a chemical reaction that every beginning analyst uses—

$BaCl_2 + Na_2SO_4 = BaSO_4 + 2NaCl$—and say, "Young man, here is your problem. Imagine this barium sulfate is a product you have to make on a large scale. You have learned the chemical and physical laws involved. Now tell me what kind of an equipment you would use in order to turn out this stuff on a production basis of 10 tons a day. You have to supply power, pipe lines, buildings, and although you are not required to submit figures, try to consider the cost. Now, go home, and figure on it." It seems that examples of this kind would help to correlate many of the laws and facts he memorized but which he did not know how to use.

Another score on which we may complain of the young chemist is his attitude toward routine. Generally we class as routine work both analytical and plant control, and designate as research the higher types, including the development of new processes. Hence, routine usually refers to work which is repeated as a regular practice. Although in the development of a procedure we may have reached a point which seems good enough for our purpose, it cannot be said that a point of perfection has been reached, for this is humanly impossible. Now if there is room for improvement what business has a technical man to lose interest? Why the talk about deadly routine? It is evident that the fault is not with the work, but with the chemist. If we admit that the routine character of work will excuse the chemist's lack of interest, we might just as well stop research, because research work as a rule is built upon a great mass of routine data.

From this we can see that in order to obtain reliable data we have to stimulate the young chemist to find interest in his work. To show how interest may be created, let us turn our attention to the testing of shipments. In the majority of cases shipments of raw materials and products are billed on the basis of chemical analysis. Let us assume there is an assignment of raw material worth 5 cents a pound and say of 100,000 pounds net weight. In this case each 1/10% error in the analysis will make a difference of five dollars in the amount the employer has to pay. The chemist, who weighs the extra time spent on more accurate analysis against the gross cost of analytical inaccuracies makes a very important contribution and never complains of the deadliness of routine.

The good routine chemist must have the makings of a research chemist in order to move ahead. It does not make any difference whether research work is done in the laboratory, or out in the plant, or in laboratories on a semi-large scale. The essential qualities are the same in all cases, *i. e.*, keen observation, vivid imagination, a very high concentration of logical mind, almost unlimited patience combined with a lot of will power to do hard work. Of course, being an indirect or a direct part of a productive organization, we all have to form the habit of considering cost. This is especially true of a technical man who directly participates in the productive end, for the production man has to earn his pay each day; other-

wise there is no place for him in the economic system. This also applies to the "trouble hunter"—the works chemist. The research man working on development of a new branch does not have to consider cost in this form. He is accumulating data for a future plant that is to pay back all the capital invested in the research venture. His immediate concern is to get his data at the lowest possible cost. But he must not forget that over a longer period his average balance of salary received and earned must be productive or he cannot survive.

We have followed the chemist through successive steps from routine to research. To develop further, he must be responsible for other people's work. He must have executive ability. Like other characteristics, this talent may be a gift, but it may also be acquired to a certain degree. It eventually becomes a matter of common sense. He must treat people in such a way that they will like him well enough to do things for him. In this way he will be a success. The chief factor is justice. Justice will get a man's attention and that intangible thing—his initiative, which can be gotten by no other means. No matter how low his position at the start or high he may have risen, no chemist can go wrong by treating people with justice.

The chemist's chief duty is to save money in an industrial plant. It follows logically that any person connected with a plant who wants to become an important factor in that organization, must be capable of earning money for the company. He must be on the credit side of the ledger, delivering enough to warrant his salary. The ultimate success is finally summed up in the check received monthly. This is not the only thing that inspires us to do good work. We must be in love with our work, but unless we get proper remuneration for it, our victory is not complete and the only way to rise higher is to develop more.

To summarize I would list as the most important assets of an industrial chemist:

(1) Knowledge of fundamentals—the result of systematic training.
(2) The ability to analyze mistakes and make sure they will not reoccur.
(3) The habit of going over the same thing again and again, trying to get a new angle.
(4) Appreciation of economy—never forget cost.
(5) Power of concentration—be on the job every moment.
(6) The determination to treat people as one would like to be treated.
(7) When in doubt, the ability to weigh matters from the point of view of the owner, and finally
(8) High ideals; never lower the standard under any provocation.

PHYSICAL CHEMISTRY FOR UNDERGRADUATES*

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In the family of undergraduate chemical courses physical chemistry has been the step-child. As a subject of instruction it originated in the advanced lecture courses such as those which subsequently appeared in the books of Ostwald, van't Hoff, Arrhenius, and others. Only in very recent years has it been taken into the family of undergraduate courses, and in its new surroundings it has had to exist on the left-overs of time, and such hand-me-downs of content and method as were brought from the older establishment. We have been very slow to give to our elementary instruction in physical chemistry the same original thought, practical application, and pedagogical skill that have characterized our teaching of general chemistry.

It is not intended to imply that the hand-me-downs are not of great value. On the contrary, the elementary course may well make full use of many features of the more advanced courses, both because of their inherent worth, and because as heirlooms they are of great historical interest. But we are now thinking particularly of the students whose undergraduate instruction in chemistry is necessarily limited to about one-fourth of their time. This group includes pre-medical students, together with those majoring in chemistry with a view to graduate or technical work in the subject. For such students as these, it is necessary to present physical chemistry in a manner which is very different from that customary in more advanced instruction.

Theoretical Instruction Essential

There is no necessity for arguing the need of such students for instruction in chemical theory. The survey of elementary chemical instruction recently presented by Professors Cornog and Colbert[1] shows clearly that college teachers appreciate fully the importance of this phase of the subject. Furthermore, physical chemistry is now being recognized as an essential prerequisite to the study of biology and medicine, so that there is no escape from the necessity of providing courses with such time as can be found.

But while the development of chemistry itself and the demands of other related subjects necessitate a larger emphasis upon chemical theory, this cannot be realized by any increase in the time devoted to the subject by the class of students we are considering. The required courses in science and modern language are already so numerous that it is quite impossible for many of these students to study the cultural subjects which one *must*

* Read before the Division of Chemical Education at Washington Meeting of the A. C. S., April 24, 1924.

[1] THIS JOURNAL, **1**, 5 (1924).

have to be really well educated. There arises, therefore, the very serious question whether we are making the best use of the time now available for the chemical training of this class of students.

But while we may be agreed that the chemistry curriculum of this generation must give a larger place to chemical theory, there is room for debate when we consider the time and method most favorable for its presentation. At the present time, the great majority of the students under consideration pursue approximately the following sequence of courses: general chemistry, qualitative analysis, quantitative analysis, organic chemistry, and finally, usually in the second semester of the Senior Year, physical chemistry. While there are variations in detail, the student's instruction in theoretical chemistry is generally started in his Freshman Year, when he gets a superficial glimpse of some of the principles. In connection with his analytical chemistry he has an occasional lecture in which certain principles are elaborated somewhat more in detail. Finally, he attempts to study physical chemistry systematically for about one semester, after he has finished the bulk of his work in the other branches of chemistry.

Theoretical Instruction Too Late and Superficial

Without attempting any thoroughgoing criticism of this conventional curriculum, let us consider two of its weak features. In this scheme of instruction, chemical theory is scattered over almost the entire course, but at no place is it sufficiently concentrated to have any great or lasting effect upon the student. In the ideal case, two such effects should follow the instruction in physical chemistry. It should benefit the student, first, by giving him an insight into the *reasons* for laboratory procedures. Knowing these, he is in a position to judge which procedures must be followed rigidly, and which only in a general way; he thus becomes a more expert and intelligent laboratory worker. Not only so, but a student should obtain from physical chemistry a sufficient grasp of the theoretical principles to serve him as a guide in reasoning independently about chemical phenomena. If he should subsequently go into biology or medicine he ought to carry over enough chemical theory to profit him in the interpretation of the chemical phenomena of his new field. But when the systematic course is postponed until the latter half of the last year, it is too late to help the laboratory work of analytical and organic chemistry; and the attempt to meet medical requirements by covering the entire field in thirty lectures results in a course less than one molecule deep, and utterly incapable of influencing very profoundly the student's subsequent thought. The undergraduate cannot gain from such a course a really satisfactory appreciation of the methods of physical chemistry, especially when they are taught with only a remote relation to his own laboratory work.

Facts First

The second criticism has to do with the content of the first course in chemistry. Feeling the growing importance of the theoretical aspects of the science, we have crowded into this course an ever increasing mass of principles. At the same time we have added new discoveries of fact and "useful applications" to the point where the present course is much larger than we can teach with any degree of thoroughness. What shall we do? Shall we stress fact or theory? According to the survey previously cited, the majority of teachers seem to favor theory rather than fact. It is difficult to see how one can really stress both without straining the students!

Probably we should all agree that the ideal method of instruction in chemistry would consist in the presentation of a set of principles so complete that we might leave to the individual student the computation of any particular fact that he might need—the color of potassium permanganate or the odor of hydrogen sulfide, for instance. This is the general method of physics. But from the pedagogical standpoint there is a fundamental difference between the principles of physics and those of chemistry. The laws of physics relate to phenomena which are more or less familiar to the student, such as friction, moving bodies, engines, electric appliances, etc. But in the case of chemistry, the beginner has no real appreciation of even the simplest facts which lie at the foundation of the principles. Before he can see any significance in the general theory of chemical equilibrium, for instance, he must know something about specific reversible reactions and the effect of a variation in the conditions. We are not yet in a position to teach theoretical chemistry to beginners without first building the foundations in facts.

If this be true, may we not look with some degree of suspicion upon the very marked tendency towards the subordination of descriptive chemistry? Is our present-day, overgrown course in general chemistry the result of a careful selection and logical arrangement of material, or is it not rather the compromised result of trying to satisfy the demands for more adequate theoretical training and at the same time cover an ever widening field of facts? Not that we should return to the easy, popular, disconnected spectacular methods of teaching descriptive chemistry; by no means. We are appealing for a thorough presentation of the most important and useful facts from the standpoint of their relations to one another and (so far as possible) to current generalizations.

A law in chemistry is said to be a description of uniform behavior. For the beginner in chemistry the most important laws are often not even called by that name, and we sometimes fail to emphasize such general matters because they are so obvious to us. Rather than have our students discourse glibly about the ionization *constant* for hydrochloric acid, would

it not be far better to have them come out of general chemistry *thoroughly convinced* that an acid and an oxide react *generally* to produce a salt and water, or that oxidation and reduction always go together and according to well defined rules? We should then not be humiliated by having second year students occasionally produce hydrogen or oxygen simply in order to balance an equation!

From the standpoint of utility, therefore, there are serious objections to our present arrangement of courses. The theory itself is taught inadequately, but even so, it is taught at the sacrifice of the thoroughness of the instruction in descriptive chemistry.

Physical Chemistry a Tool

For the class of students under consideration, is it proper to treat physical chemistry as a more or less independent branch of the science, like organic chemistry? In the highest sense thermodynamics does stand apart in just such a manner, but these students are not able to study physical chemistry from the thermodynamic standpoint. In fixing the place which is to be given to physical chemistry in the undergraduate curriculum, we should recognize that if it is to be taught effectively it must be made to appear as an immediately useful subject. It cannot be taught as an end in itself, therefore it must be furnished as *a tool to be used in organic and inorganic problems*. This is the key to the arrangement of courses to be described.

We have all felt the necessity of discussing certain parts of physical chemistry in the second course. The success of the texts of Professors Stieglitz and A. A. Noyes is evidence of this fact. The recent text of Professor Chapin is another indication of the same need. But probably in most colleges the second course in chemistry is principally a laboratory course. Consequently the theoretical instruction is once more treated to left-over sumptuous morsels of one hour a week to be shared with qualitative or quantitative analysis, or both!

The Partition of Physical Chemistry

If physical chemistry is to be taught as a tool, it is obvious at once that certain parts of the subject bear more particularly upon organic problems, and other parts upon inorganic. Instead of postponing the subject until the student has completed his organic and analytical courses, would it not be common sense and good pedagogy to *divide the subject matter of physical chemistry*, teaching each part in connection with the course in which it is used? This is the principle which has been followed in arranging our undergraduate work at the Johns Hopkins University.

According to this plan, the second course is the center of the instruction in chemical theory. But it is not enough simply to transfer the conven-

tional course bodily into an earlier year. The various principles must be taught in close relation to the laboratory work in inorganic and organic chemistry, and this requires an interweaving of subjects that differs considerably from the conventional physical chemistry. If a student in organic chemistry studies the theory of fractional and steam distillation when he is engaged in these operations in the laboratory, the theory becomes more vital, and he also makes a better distiller. Similarly, if a student has studied through one of the classic atomic weight determinations and has then attempted to duplicate in the laboratory even a small portion of the work, he has a profound respect for the atomic weight table.

With possible variation as to details, one may conveniently teach in connection with analytical and inorganic work the subjects of atomic and molecular weights, gas laws, theory of solutions, equilibrium, and electrochemical principles. In like manner, the course in organic chemistry is a good place to teach such matters as the vapor pressure of volatile mixtures, physical properties of substances, and relation of structure to properties, besides certain parts of colloid chemistry and electrochemistry.

It is to be emphasized that the presentation of these subjects is not to be superficial, as has necessarily been the case heretofore. In order that the students may have adequate preparation we require a year each of college mathematics and physics as prerequisites to the second course in chemistry. For the same reason we have transferred general chemistry from the Freshman to the Sophomore Year. No difficulty whatever was encountered in making this change, and the results have been in every way gratifying.

A Correlated Laboratory Course

The content of the second course in chemistry is a problem for which almost every institution has its own solution. It might be more accurate to say that the great diversity seen in these courses is an indication that no real solution has been found. In planning a laboratory course to accompany the inorganic part of the partitioned physical chemistry several possibilities present themselves. In any event it is desirable that the laboratory work and lectures shall be closely correlated. But a proposal that students jump from general chemistry directly into a laboratory of physical chemistry would come as a distinct shock to one who had always required quantitative analysis as a prerequisite! Furthermore, the usual courses in physical-chemical measurements include many determinations of the physical constants of compounds, which are necessary, but give very little advancement in descriptive chemistry. And as previously emphasized, it is firmly believed that each year of the student's training should include a large proportion of facts.

The value of qualitative analysis as a laboratory aid in developing the

principles is familiar. It has also the great virtue of adding largely to the student's knowledge of compounds and reactions. But have we not used very poor judgment in throwing the immature student, often a Freshman, into the labyrinth of qualitative analysis?

From the standpoint of technique, accurate qualitative analysis is a difficult subject. The multiplicity of reactions to be carried out by one who has little or no conception of what a really *complete* separation is prevents the teaching of a correct technique at the start. Only the rod of necessity will teach most students such things as absolute cleanliness and accuracy in carrying out a sequence of reactions and separations. A large class in qualitative analysis is a very poor place to teach technique originally; it is an excellent place to enforce and practice a correct technique previously learned elsewhere.

From the theoretical side, qualitative analysis affords splendid applications of the various principles; but if the course is to be really thorough, it is impossible with even three lectures a week both to present and to apply the principles *pari passu* with the laboratory work. The first week in qualitative analysis introduces such varied matters as oxidation, complex ion formation, neutralization, common-ion effect, displacement, solubility product, etc., but weeks are required in developing the theory of these things. As a consequence, the laboratory work becomes at the start a blind following of directions—an error that can be only slowly corrected later. From the very first the student needs to be able to give the theoretical interpretation of some of his procedures.

The scheme that has been worked out has been designed to develop during the first half-year a quantitative technique in the laboratory, by means of experiments chosen definitely to exemplify the principles being discussed in the class-room. This work includes molecular and atomic weights, standard solutions, vapor pressure, ionization by boiling or freezing point method, reaction velocity, the distribution laws, solubility, etc. In this work we have required and obtained the same order of accuracy that is customary in elementary quantitative analysis. Every experiment is quantitative, and the operations are few enough to permit the teaching of a correct technique. Furthermore, the experiments provide a good foundation upon which formal quantitative analysis may be subsequently taught, since they include volumetric and gravimetric methods, acidimetry, iodimetry, etc.

By the end of the first semester certain phases of the subject of equilibrium have been studied. During the second term the class takes up in the laboratory a rigid scheme of qualitative analysis, such as that of Professor A. A. Noyes. They bring to this work a good technique, the quantitative view of reactions, the habit of problem solution, and a familiarity with many chemical principles. They have learned that the principles

are not useless abstractions that serve as the basis for hard problems. They have learned much of the vocabulary of theoretical chemistry. They make better analysts in the time available, and their practice *confirms* the habit of careful work, while, at the same time, it impresses upon them the practical significance and value of the theory. The results of the experiment have been particularly gratifying in these respects.

During the second semester the lectures are largely concerned with the application of the principles to the various types of reactions involved in the analytical work. This serves the double purpose of clarifying the general chemistry and of reviewing and using the principles developed throughout the year. When the principles are first presented, only sufficient applications are given to indicate the meaning of the theory. But in the latter part of the course we take up a specific process or type of reaction and bring together all the principles which have a bearing upon it. For example, we take up the question of precipitation in general; this gives an opportunity to review and apply the following principles: distribution between solid and solution phases, ionization equilibrium, solubility product as a corollary to these, excess of a common ion, besides the use of the conductivity and electromotive force methods of measuring minute solubilities. Similarly, in discussing the composition and stability of complex ions one can profitably indicate the use of the following tools: ionic migration and mobility, freezing point, solubility, electromotive force, distribution laws, etc.

One plan would be to teach a principle and then show the variety of problems which it can be used to solve. The other alternative is to teach the principles with a minimum of practical application, and then to bring all available principles to bear upon the various problems to be considered. In our experience the latter plan gives excellent results. It has the advantage of constant repetition, the various principles being brought up again and again in different combinations and for different purposes. It makes the entire subject coherent, and at the same time reveals the significance of the inorganic chemistry.

By-Products

Students take great interest in theoretical chemistry when they can see its relation to laboratory problems. It is believed that the plan which we have outlined has a healthy catalytic effect in stimulating the interest of good students in advanced chemistry. And in addition, by coming in contact with so many of the more recent developments of the science in a somewhat historical manner, they gain an appreciation of the methods and labor involved in the present attainments in research. These are valuable results.

But in addition, there is also a negative catalytic effect in some cases which is also very fortunate. Some students attempt chemistry who are endowed by nature with traits which they could use to far greater advantage to all concerned in some other field of endeavor. On the one hand, good laboratory work seems impossible to an occasional student. One or two quantitative experiments give tactful but inexorable indication of such cases, and it is a real service to direct such students into other lines.

Furthermore, all branches of chemistry and even its dependent subjects are now highly dependent upon mathematics. Not long ago there was a class of thirteen teachers of medicine engaged in the study of higher mathematics! It would seem to be unwise to encourage a student who is fundamentally weak in mathematics to attempt a chemistry major, and the suggested plan gives due warning before it is too late.

In the preface to his *Grundlinien der anorganischen Chemie* Ostwald lamented the fact that chemistry had been taught in such a manner as to permit unfavorable comparison to the rigid methods of instruction in physics and mathematics. There are probably still a considerable number of teachers who present chemistry in the easy, semi-popular way. In all but the smallest institutions, however, it ought to be possible to make a division as between students who take chemistry as one of their cultural subjects on the one hand, and on the other hand, those for whom at least three college courses in the subject are required. For the first group, a general course including some of the "Pandemic" suggestions might be proper. But for the second, there is a pressing need that we organize more rigid courses in accordance with a logical and coherent plan covering at least three years. The content of each course should be fixed in relation to the entire plan. In such a scheme physical chemistry would receive the fair treatment which it so well deserves.

Summary

1. The paper discusses the instruction in physical chemistry for those undergraduates who devote about one-fourth of their time to chemistry (including pre-medical students and others).

2. The instruction in physical chemistry has an illogical position in the curriculum, since it comes too late to benefit the other chemistry courses, and is too superficial to be of much help in subsequent work.

3. Physical chemistry for these students is a tool, and should be taught earlier than the Senior Year.

4. It can be taught most effectively by dividing the subject matter on the basis of its relation either to inorganic chemistry or to organic chemistry.

5. The arrangement of the undergraduate courses at the Johns Hopkins University has been made on this basis.

Discussion

Prof. Patterson, Antioch College. I noticed that Dr. Cartledge said they have two beginners courses now and we for the past year have had the same in Antioch, that is, one course for those who are expecting to go on and specialize in chemistry and one for those who are not and I suppose this is just the case at Johns Hopkins. This does not mean that the course is a snap in fact, a little more work is required. Emphasis is put in a different place and I just want to ask if we have other institutions which are doing this. I am glad to know that Johns Hopkins is doing it. I would like to compare experiences.

Prof. Brinton, Univ. of Minn. At the University of Minnesota we have a great many different courses in freshman chemistry and we entirely segregate those who are to be chemists from the regular academic students. We demand of them much more intensive work and perhaps a little more strict grading sometimes is used, feeling that is the time to weed out and we have separate courses also for the Pre-medical and also for the academic, but the huge number that we have to deal with there makes it necessary.

CALCULATING THE RESULTS OF A VOLUMETRIC ANALYSIS

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One finds a variety of terms employed by different authors of tests and reference works on quantitative chemical analysis in their discussion of the standard solution. Frequently the solution is stated to have a "value," or one is directed to calculate its "value," but there is no indication of whether "value" refers to the concentration of active reagent per ml. of standard solution, to the solution's normality, or to the weight of some substance with which this active constituent will react. Several expressions are substantially synonymous when used in this connection such as one ml. "shows the presence of," "corresponds to," "is represented by," "reacts with," "is equivalent to," or "equals." These, however, all refer to the constituent being determined by means of the standard solution.

In the ordinary, direct volumetric determination of a substance, the information necessary for the calculation of the percentage of the desired constituent involves the weight of sample, volume of standard solution used, and value of the standard solution. In general, the latter quantity is expressed in terms of grams per ml., normality, or the weight in grams of the desired constituent with which one ml. of the standard solution will react or to which it is in any way equivalent.[1] Knowing any one of these values, the other two may be calculated readily if desired.

Depending upon the basis employed in expressing the value of the stand-

[1] See Foulk, "Quantitative Chemical Analysis," **1914,** p. 100.

ard solution, several formulas may be deduced which are an aid, both in showing the general relationships involved and in making the actual calculations for an analysis. These formulas are included in the following:

$$\frac{V \cdot N \cdot EW}{S \cdot 1000} \cdot 100 = \%^{2} \qquad (1)$$

$$\frac{V \cdot N \cdot mEW}{S} \cdot 100 = \%^{3} \qquad (2)$$

$$\frac{V \cdot C \cdot F}{S} \cdot 100 = \%^{4} \qquad (3)$$

$$\frac{V \cdot N \cdot M}{S \cdot 1000 \cdot 2} \cdot 100 = \%^{5} \qquad (4)$$

$$\frac{V \cdot E}{S} \cdot 100 = \%^{6} \qquad (5)$$

In the above expressions the letters have the following significance: S, weight of sample in grams; V, volume of standard solution in ml.; N, normality of standard solution; EW, equivalent weight of the constituent being determined, in terms of hydrogen equivalents; mEW, milli-equivalent weight of the same; C, concentration of the standard solution in grams per ml.; F, factor for calculating the weight of the desired constituent equivalent to C; M, molecular weight of the substance determined; A, activity (hydrogen equivalent) of the substance determined; and E, the weight of the desired constituent equivalent to one ml. of the standard solution, or with which one ml. of the solution reacts.

It is evident that

$$E = \frac{M}{1000 \cdot A} = C \cdot F = N \cdot mEW = \frac{N \cdot EW}{1000}$$

In discussing such calculations with students the term "equivalence" has been adopted to designate the quantity represented by E, and it is defined as already mentioned. The purpose of the present note is merely to call attention to the definition of the term, to point out its relation to the other terms ordinarily used in such calculations, and to suggest the desirability of its use. No particular merit attaches to the word selected probably a better one could be found—but the practice of presenting the material in this manner has worked well with the author's classes.[7] When-

[2] Ashley, "Chemical Calculations," **1923,** p. 211.

[3] Hamilton and Simpson, "Calculations of Quantitative Chemical Analysis," **1922,** p. 81.

[4] Mahin and Carr, "Quantitative Agricultural Analysis," **1923,** p. 6.

[5] Blasdale, "Quantitative Analysis," **1914,** p. 250.

[6] *Ibid.*, p. 247.

[7] NOTE.—It should be noted that the term has been used occasionally in a different sense in such statements as, "Equivalence of volume among normal solutions." Foulk, "Quantitative Chemical Analysis," **1914,** p. 108.

ever a solution is standardized, a record is made upon the label on the stock bottle of the equivalence of the solution in terms of each constituent to be determined by means of the solution. Reference to formula (5) will show that we then have involved the simplest calculation in order to obtain the result of an analysis.

In a paper presented in 1922 before the December meeting of the Indiana Academy of Science, E. G. Mahin discussed some of the objections to adhering too closely to the normal system in preparing standard solutions He pointed out that, in many instances, it is desirable to prepare the solution approximately of the concentration desired and then to determine what is here designated as its equivalence. One saves the time necessary to adjust carefully a solution prepared on the normal basis, and the calculations are just as simple except in those rare instances when the equivalent weight of the constituent being determined is a whole number. A tenth normal solution of sodium hydroxide, for example, has an equivalence of 0.003646 in terms of hydrochloric acid (that is, one ml. of the sodium hydroxide is equivalent to 0.003646 g. of hydrochloric acid); one prepared only approximately tenth normal (actual value 0.1012 N, for instance) has an equivalence of 0.003690 in terms of hydrochloric acid, a value just as easy to use in calculations as the preceding one.

When the equivalence for any given substance is a simple multiple of a gram, we then have the value of the solution expressed in terms of the "decimal"[8] or "unitary"[9] system. A solution so adjusted has the advantage for "direct reading" determinations over one whose equivalence is not a simple multiple of a gram in that a simple fraction of a gram of sample is then required.

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IN AND OUT OF THE CLASS-ROOM WITH DOCTOR EDWARD WILLIAMS MORLEY

C. C. KIPLINGER, MT. UNION COLLEGE, ALLIANCE, OHIO

In the fourth of a series of articles by Doctor Edward Hart, "Chemical Age," V. 30, 12, 541, "Random Recollections of an Old Professor," is the following paragraph; "I never heard Doctor Morley lecture to his students, but I imagine that he must have been a great teacher and so must Dr. Wiley. They were linguists and masters of the language; they were kind, painstaking and patient; they were distinguished and commanded respect." Recently, several excellent sketches of Doctor Morley's life and activities have appeared in the literature ("Science," April 13, 1923, 431; "Reserve

[8] Mahin, "Quantitative Analysis," **1909,** p. 202.
[9] Blasdale, *Loc. cit.*, p. 247.

Bulletin," Vol. 26, 8, 58; "Jr. Chem. Soc.," 123, 3435–40, 1923). The writer desires to add a few of his personal experiences as a student in general chemistry under Doctor Morley to these records.

In the first place, like Doctor Hart, I never heard Doctor Morley lecture in the class-room. He did not believe in lecturing to beginning students and we were frequently reminded that we had never acquired the art of taking notes and were much inferior to the western students in this matter. The text used (1903–04) was Newth's "Inorganic Chemistry," a volume of somewhat imposing size and content. The topic method of recitation was utilized almost universally in the class-room. Doctor Morley would call on a student to start the discussion of some subject, allow him to talk for three or four minutes while on his feet (if he could), and then call on a second student to take up the discussion where the first had dropped it. Doctor Morley disliked very much to be forced to ask leading questions which would aid the pupil in his discussion. However, he would frequently stop a recitation to criticise a peculiarity of speech or blunder in English. This method required a much more careful and intensive preparation of the lesson than the average class-room procedure of the present day.

On one occasion when reciting, I was halted by Doctor Morley and requested to repeat the word "and," I did so and the request was made again. This happened several times and finally, having reached a state of extreme mental confusion, I expressed my inability to understand the situation. He replied, "You have been saying "and" this way, 'and-a'." He was always willing to give his time and attention to correcting individual defects of this type, matters that are usually passed over as unworthy of notice by a more careless teacher. It was such experiences as the above that added daily to our appreciation of and affection for Doctor Morley. If he happened to see any one peeking into the text-book during the recitation, a motion of his hand in the direction of the door caused the offender to leave the room. There was a total absence of sarcasm in the class-room atmosphere. He was very sparing of words and preferred that we do the talking while he took on the relation of a kind critic and guide to the struggling student. He always avoided any ostentatious display of his marvelous knowledge.

Two favorite quotations stand uppermost in my mind as he repeated them a number of times during the year's work.

> "Oh, wud some mon the giftie gie us
> To see oursilves as ithers see us," etc. and;
> "Be not the first by whom the new is tried,
> "Nor yet the last to lay the old aside."

I remember well my first experience in the chemical laboratory on the third floor of Adelbert Hall. Doctor Morley and an assistant were initiat-

ing us into the mysteries of elementary experimentation. I had just completed writing the purpose of the experiment when Dr. Morley came to my desk and suggested a change in the wording, which I made. A few minutes later the assistant came by and on picking up my note-book found fault with my revision. Feeling student-wise that I had a grievance, I made haste to call Dr. Morley's attention to the matter when he came to me the second time, whereupon he remarked very kindly, "You do it my way;" and this was the end of the matter.

His seemingly ever present nod and smile were the outward manifestations of much of his philosophy of life. By virtue of his training and tendencies he was a very religious man. Of all the Faculty, he was the one punctual and regular chapel attendant at "prayers," as he called the chapel exercises. Yet he was not intolerant of those who were less painstaking in such matters. I happened to be studying the elements of blow-pipe analysis under Professor X, who, one morning was demonstrating the use of the blow-pipe in producing the oxidizing and reducing flames. We were in the chemical laboratory and some air currents were in evidence. Doctor Morley came into the room just as Professor X exhausted the last remnants of his patience, and remarked testily;

"Morley, it's D— drafty in here.

I sat up with a jolt, wondering how Dr. Morley would receive this breach of class-room etiquette. The inevitable nod and smile were followed by a laughing "Yes! Yes!" and the tension disappeared.

Doctor Manchester of Alliance, Ohio, also a former student under Doctor Morley, tells this story. Professor A, one time teacher of physiological chemistry in the Western Reserve Medical School, refused to give credit for the course in physiological chemistry given at Adelbert College under Doctor Morley's supervision, which occasioned the following gentle rebuke;

"Well, I taught Professor A what little chemistry he knows."

While lecturing on the subject, "The Michaelson-Morley Effect" before a group of Cleveland citizens and students, Dr. Morley remarked that at one time he could write the Lord's Prayer in the space covered by an old fashioned three cent silver coin, but that he was not able to do this now, whereupon someone who was sitting back of me remarked in a low voice, "Perhaps he has forgotten the Prayer." During the progress of this lecture Dr. Morley stated that out of eight of the most fundamental experiments in light performed up to that time, he had been connected with four and one-half of the investigations.

One morning as I was hurrying from the street car to Adelbert Hall, I happened to meet Dr. Morley on his way to the laboratories. He greeted me very pleasantly, and during the course of the conversation which followed, mentioned some work which he was carrying on with anastigmatic

lenses. It was reported among the students that he was making a gold flute in the hope of getting a better toned instrument by the use of this valuable material. In fact, the scope of his scientific interests was extraordinarily wide.

Doctor Morley was a skilled glass worker. He was very adept at sealing together trains of glass apparatus. In his work, "On the Densities of Oxygen and Hydrogen," Smithsonian Contribution 980, 85, he describes an elaborate piece of glass apparatus which had required an unusual amount of his patience and skill for its construction, and remarks: "The apparatus worked without failure until a heedless plumber knocked a brick through the wall, without even looking to see what damage might be caused, and crushed it into a hundred fragments." He frequently referred to a glass stop-cock as "a located leak." His hand blow-pipe, a form which he devised and used with great skill in the manufacture of his complicated glass apparatus, together with much of the apparatus itself, are still preserved at Adelbert College.

At one time he appeared at a meeting of the Cleveland Section of the "American Chemical Society" with his face swathed in bandages, having suffered from numerous cuts resulting from the explosion of residual gas mixtures in a number of large glass globes which he had used in his earlier experiments with oxygen and hydrogen. His loyalty to the Section brought him to the meeting in spite of his painful injuries.

Denied the blessed experience of fatherhood, Doctor Morley was a lover of children. The late Doctor H. P. Cushing stated that Dr. Morley delighted to go to the nursery and play with the children while visiting at the Cushing home.

In concluding this brief series of somewhat incomplete and perhaps seemingly trivial glimpses into the life of this master man, the writer, as one of a large group of loyal students, will never cease to thank the good fortune that brought him into contact with this most remarkable personality, the man of patience and sympathy, of skilled hand and marvelous mentality, who, as his ever widening interests and invaluable achievements gained world-wide recognition, maintained the helpful and humble spirit of the Greatest of all teachers.

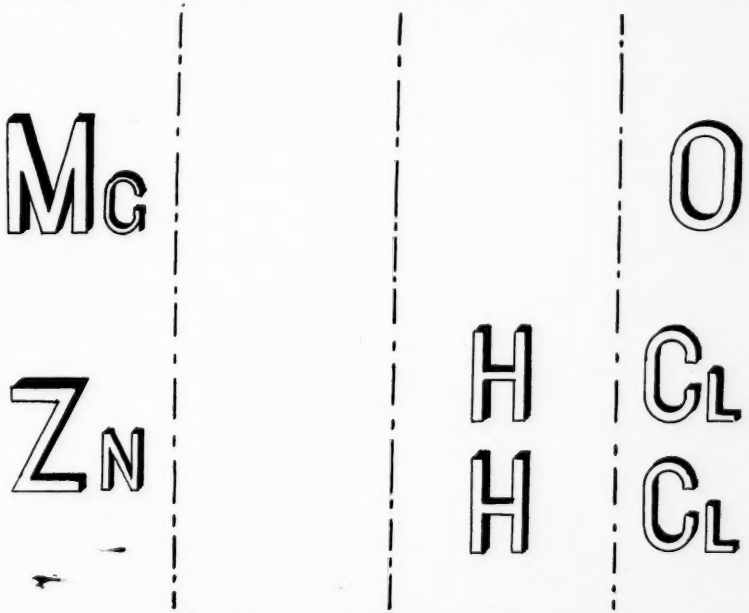
CHEMICAL REACTIONS VISUALIZED FOR BEGINNERS*

HAROLD J. TURNER, MONTCLAIR, N. J.

In beginning the study of chemistry the use of symbols in formulae and in the writing of equations to express chemical reactions is a part of

* Read before the Division of Chemical Education at the New Haven Meeting of the American Chemical Society.

the study that presents some considerable difficulty to the student. The symbols which we are accustomed to use are the letters of the alphabet, and these letters do not carry any idea of mass, or substance. These letters are the symbols each for a different sound. In the study of algebra, the letters have been used to represent abstract mathematical quantities, or magnitudes. They do not of themselves suggest mass, or substance. Now, in chemistry each symbol is to represent a perfectly definite mass, or weight, a very small particle of an element, called an atom. It becomes



The creases are made by folding: 1. Into halves, with symbols inside. 2. Into quarters, by folding back the outer free ends, showing the symbols.

Upper half: To show the *burning* of magnesium ribbon, which is the combining of the element magnesium, Mg, with oxygen O, at somewhat elevated temperatures to form the magnesium oxide, you are to fold so as to bring one Mg (24.3 parts) and one O (16 parts) close to each other. This illustrates the equation: $Mg + O = MgO$.

Lower half: To show the *preparation* of hydrogen from a metal as zinc, and an acid, as hydrochloric, by the displacement of the hydrogen of the acid by a metal which is more electro-positive than the hydrogen, you are to so fold that the one Zn (65.4 parts) falls on the two H (2×1.008 parts) of the acid, taking their place, forming zinc chloride ($ZnCl_2$) and liberating gaseous hydrogen (H_2). This illustrates the equation: $Zn + 2HCl = ZnCl_2 + H_2$.

necessary to teach the beginner to associate the idea of mass, or substance, with the letters as used in chemical formulae.

We find that a letter drawn in prospective does convey very readily the idea of mass, or substance.

In the accompanying plate burning as oxidation is illustrated; also,

in the lower half, one can readily visualize the displacement of hydrogen by a metal from an acid. In this manner we present to the beginner such a topic as neutralization of an acid by a base on the ionic theory and it is simplicity itself. The mechanics of the reaction can be easily grasped by the beginner in a way that both interests and instructs at the same time. Many of the great generalizations of the science of chemistry become readily intelligible to the enthusiastic beginners.

A NEW USE FOR THIS JOURNAL

There seems to be an increasing number of colleges and universities planning courses in chemical education for the coming year. Some of the instructors responsible for these courses have already adopted THIS JOURNAL as one of their text-books. If this unexpected use increases, the editors must try to improve THIS JOURNAL so that it will better meet this new situation. Two improvements have already been suggested: One is to have each issue contain an article which has to do with pure methods in chemical education, *i. e.*, education psychology applied to chemical education; a second suggestion is for THIS JOURNAL to contain abstracts of articles on chemical education found in other journals.

All subscribers who wish THIS JOURNAL to function in this new field by incorporating these two suggestions, will notify the editorial office at once. Also send any other suggestions.

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Local Activities and Opportunities

The New England Association of Chemistry Teachers: At the Malden Massachusetts High School on March 15th was held the 25th Anniversary of the founding of the Association. The first president, Dr. Lyan C. Newell of Boston University, and tenth president, Mr. Wilhelm Segerblom of Philips Exeter Academy, delivered the principal address. Mr. Segerblom was elected to honorary membership in recognition of his long, faithful and effective efforts in behalf of the Association.

In commemoration of this 25th anniversary meeting, a report of unusual completeness has been issued. This contains the unabridged report of "The Earlier and Later Days of Chemistry in New England," is illustrated by choice photographs of some of the more prominent older New England chemists selected by Dr. Newell, who is well qualified to deal with the subject, having made the history of chemistry a lifelong study. This special report will also contain the complete report on the Laboratory Questionnaire by Mr. Wilhelm Segerblom. Both of these papers will be valuable contributions to the literature of their respective subjects.

A great demand for this special number has been anticipated, and to meet this the Association has printed a large number of extra reports, and will supply copies to non-members and *extra* copies to members at fifty cents per copy. Order from Mr. Laurence R. Atwood, Secretary, Malden High School, Malden, Mass. Send cash with order.

The Spring Meeting of the Western Division of this Association was held at Mt. Holyoke College, South Hadley, Mass., on Saturday, May 3rd, in connection with the regular meeting of the Connecticut Valley Section of the A. C. S. After and interesting trip through the Whiting Paper Company's Mill No. 1 at Holyoke, the company adjourned to Shattuck Hall, So. Hadley, where Prof. A. J. Hopkins of Amherst College gave an illustrated paper on "Egypt, The Land of the Alchemist."

Following the afternoon business meeting at which thirteen new members were elected, Mr. Robert Langdale of New Haven, Conn. High School gave a series of five lecture table experiments demonstrating spontaneous reaction.

The concluding feature of the afternoon program was a lecture by Prof. James Kendall of Columbia University entitled "The Abuse of Water by Teachers of Chemistry." After critically examining certain of the fundamental concepts of the conventional theory of electrolytic dissociation, Dr. Kendall summarized the main points of a so-called "rational theory" of ionization wherein the familiar phenomena may be shown to be the result of varying degrees of compound formation between solvent and solute. This theory is being developed at Columbia University and aims to put the chemistry of solution on a perfectly general basis and not on a strictly water basis as maintains at present.

Most of the members remained for the evening meeting of the Connecticut Valley Section of the American Chemical Society at which Professor Bogart of Columbia gave a lecture on perfumes illustrated by about two hundred colored lantern slides.

Northern Division Meeting: On Saturday, May Tenth, despite inclement weather, about thirty members gathered at Concord, N. H. The morning was devoted to a trip through the Rumford Press, a thoroughly up-to-date plant, about seventy-five per cent of whose business is the printing of such periodicals as The Atlantic Monthly, Century, etc.

After luncheon and the short business meeting held at the Concord High School at which eight new members were elected, Mr. Elwin Damon of Keene, N. H. High School gave a talk on the teaching of "Chlorine."

Professor Charles James of the University of New Hampshire gave a most interesting lecture on his favorite theme, "Metals," showing many specimens of the rare ones and dwelling at length on the difficulties that are encountered in obtaining pure samples of many including the rare earth elements.

Mr. W. K. Robbins, chief chemist of the Amoskeag Manufacturing Co., read a paper entitled "The Chemist in a Textile Mill," touching on the various problems that such a chemist has to solve and stressing the necessity of teaching elementary chemistry students the fundamental general principles of chemistry. The meeting concluded with an informal talk by Mr. Churchill of Eimer and Amend Company on the possibilities of Laboratory apparatus of clear fused quartz of the sort that has recently been made by Mr. Berry of the General Electric Works at Lynn, Mass.

The Association is now operating in four of the six New England States, has a New England-wide membership of 400, including representatives of nearly all New England colleges, and is about to begin on a campaign to raise its membership to the 500 mark. It will then endeavor to farther extend its operations geographically.

Prof. Martin V. McGill, of Lorain High School, Lorain, Ohio has been elected Chairman of the Chemistry and Physics Section of the Northeastern Ohio Teachers' Association.

A Unique Laboratory "Open House." The Alchemist Club and the chemistry faculty of Vanderbilt University were "at home" on the evening of February 20th to the citizens of Nashville and surrounding territory. For several hours the halls of Furman Chemical Laboratory were crowded with people of every age and occupation. The Exhibits were so unique and of such variety as to enthuse even the "hardened" scientist; to those without chemical training the spectacular displays presented the most fascinating mysteries. The interest aroused in the city has gone so far in stimulating an appreciation of chemistry as a practical science, that details of the exhibit are given with the hope that they may be of assistance to other teachers of chemistry in planning similar public occasions.

In the basement, electric furnaces were at red heat; plating baths were depositing; metals were being polished and etched for examination under the microphotographic camera. The repair shop had a sign, "Everything Mended but Broken Hearts."

On the first floor, an extensive display of Welsbach gas mantles was glowing brightly. A collection of isotopes interested advanced students, but the laymen passed them by. In the physical chemistry laboratory, complete equipment for electrometric titration, sugar analysis, radium determination, and high vacuum work attracted attention. Even the molecules performed for the visitors, for an ultramicroscope was a feature of one room.

On the second floor the analytical laboratories were making determinations of "everything under and in the sun." A miniature sulfur well was in operation. Both the Junker and Bomb calorimeters were competing with each other for speed and accuracy on analyses of gas and coal samples. Many other industrial processes were represented in laboratory operation. The organic laboratory carried as its motive, "Products of the South—Corn, Coal, Cotton." Starch, sugar, and syrup manufacture; the diversity of corn-cob products; the uses of corn oil; the different types of distillation; these represented the first C. Miniatures and specimens from the manufacture of coal gas, tar, intermediates, dyes, drugs, flavors, etc., illustrated the second C, Bakelite and saccharine were prominent in this group. For the third C, a textile exhibit, cotton in all its stages of growth, cotton seed oil and its many products, made the public aware of how close chemistry was to many familiar objects of daily life.

On the third floor the freshmen chemistry students did the honors. For once the laboratory was admittedly a playhouse. Each student chose that chemical "stunt" which to him seemed most thrilling and for the entire evening the smoke rings, the explosive mixtures, the gay solutions, and dozens of other spectacles were carried on continuously as the citizens filed by. And each freshman, finding for once some simple soul that knew less chemistry than he, explained his particular dramatic scene with a dash and swagger that was really inspiring.

In the auditorium continuous motion pictures were shown, three industrial films being used.

The Open House was under the direction of a general committee from the Alchemists Club, of which J. H. Folkerth is president. A faculty group coöperating consisted of Dr. J. M. Breckenridge, Director of the Laboratories, Dr. A. W. Ingersoll, Dr. L. J. Bircher, Dr. F. L. Conover, and Professors W. P. Fishel, E. G. Haas, R. B. Isley, R. C. Carlowitz.

BOOK REVIEWS

Aniline and Its Derivatives, by P. H. GROGGINS, B.S., D. Van Nostrand Company, New York, 1924. vii. 256 pp. 23.15.5 cm. 29 illustrations.

This book presents a detailed account of the manufacture of aniline and some of its most important derivatives, together with a description of its physical and physiological properties. Its real purpose is, however, much broader. The author states in the preface that "the technique in the production of aniline has been used as a vehicle for presenting to the reader the business of plant chemistry."

Types of apparatus and operating conditions are described in detail, so that the reader may, with a little imagination, apply the information to other processes as well. The inclusion of cost data and an extended discussion of costs and operating efficiencies add greatly to the value of the book.

The work should be of great assistance to the advanced student of industrial chemistry, and particularly to the beginner in the chemical industries, as a means of bridging the gap between the usual text-book knowledge and actual plant conditions.

Textbook of Cellulose Chemistry, by EMIL HEUSER, translated from the Second German Edition by CLARENCE J. WEST and GUSTAVUS J. ESSELEN, JR. McGraw-Hill Book Company, Inc., New York.

In this book, Dr. Heuser has made an eminently successful attempt to correlate and explain the derivatives and reactions of cellulose on the basis of its formulation as an aliphatic alcohol and a polymer of anhydrocellobiose. He has assembled the scattered and apparently unconnected facts in a concise and readable manner, so that they may be easily understood by one who is not a specialist in this field.

The only disappointment is that the combination of anhydrocellobiose units is explained on the basis of partial valences. It is to be hoped that some more satisfactory explanation may be found.

On the whole, the work is an excellent presentation of a difficult subject. The translators are to be congratulated for making it available to English-speaking readers.

UNIVERSITY OF MARYLAND. GARDNER.